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**Conclusions of the NPCC 2003 Blackout Investigative Team**  
**Assessing the Power System Collapse of August 14, 2003**

**Prepared by:**

**NPCC 2003 Blackout Investigative Team**  
**August 13, 2004**



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## 1.0 Introduction

Immediately following the power system collapse of August 14, 2003, NPCC formed the NPCC 2003 Blackout Investigative Team (BIT) which was given the following charge by Mr. Charles J. Durkin, Jr., the Chair of the Northeast Power Coordinating Council:

- Develop a detailed sequence of events which the NPCC Areas experienced on August 14, 2003;
- Develop a detailed analysis of the events that resulted in the cascading collapse of a major portion of the NPCC Region on August 14, 2003, and a sequence of the restoration of the Areas and areas for investigation; and
- Based on the lessons to be learned, develop findings, conclusions and recommendations for the NPCC Areas of investigation, including the restoration effort.

These charges would focus on answering two critical questions: “What went wrong in NPCC?” and, second, “What went right?” Recommended revisions or enhancements to practices and criteria would follow from the answers to these questions. Further, the efforts of the NPCC 2003 Blackout Investigative Team complemented the input to the numerous investigations conducted in parallel by the NERC and the U.S.-Canada Power System Outage Task Force.

To ensure the necessary breadth of expertise and authority for such a task, the BIT was composed of the following individuals and NPCC groups:

### Members, NPCC 2003 Blackout Investigative Team:

Edward A. Schwerdt	Northeast Power Coordinating Council
<b>Chair, NPCC BIT</b>	

Officers of the NPCC Reliability Coordinating Committee During the Course of the Investigation:

Colin Anderson	Ontario Power Generation, Inc.
<b>RCC Vice Chair, November, 2003-December, 2005</b>	
H. Kenneth Haase	New York Power Authority
<b>RCC Chair, January, 2002-December, 2003</b>	
William Longhi	Consolidated Edison Company of New York, Inc.
<b>RCC Chair, January, 2004-December, 2005</b>	
Paul M. Murphy	Independent Electricity Market Operator
<b>RCC Vice Chair, January, 2004-December, 2005</b>	

Barbara Robertson	Ontario Power Generation, Inc.
<b>RCC Vice Chair, January, 2002-November, 2003</b>	

Howard Tarler  
Ronald J. Halsey  
**Chair, NPCC Compliance Monitoring and Assessment Subcommittee**

Members, NPCC Task Force on Coordination of Operation:

Donald L. Gates	ISO New England Inc.
<b>Chair, NPCC Task Force on Coordination of Operation</b>	
Pat Doran	Independent Electricity Market Operator
<b>Vice Chair, NPCC Task Force on Coordination of Operation</b>	
Glenn W. Brown	New Brunswick Power
Michael C. Calimano	New York ISO
Gratien Charest	Hydro-Québec TransÉnergie
John G. Mosier, Jr.	Northeast Power Coordinating Council
Clarence Penwell	Nova Scotia Power Incorporated
Paul A. Roman	Northeast Power Coordinating Council
Michael Schiavone	Niagara Mohawk Power Corporation
Daniel Soulier	Hydro-Québec TransÉnergie
Paul Tremblay	Hydro One Networks, Inc.
Roger C. Zaklukiewicz	Northeast Utilities

Stephen L. Corey	New York ISO
<b>Chair, NPCC Task Force on System Studies</b>	
Larry Eng	Niagara Mohawk Power Corporation
<b>Chair, NPCC Task Force on Coordination of Planning</b>	
Philip A. Fedora	Northeast Power Coordinating Council
Francis J. Flynn, Jr.	National Grid USA
<b>Chair, NPCC Task Force on Infrastructure Security and Technology</b>	
James W. Ingleson	New York ISO
<b>Chair, NPCC Task Force on System Protection</b>	

The NPCC 2003 Blackout Investigative Team initiated its efforts on August 18, 2003, by directing creating an ad hoc working group, the NPCC Sequence of Events Working Group, to develop the critical sequence of events within the NPCC Areas on the 14<sup>th</sup> of August. The Working Group was composed of the following individuals:

Members, NPCC Sequence of Events Ad Hoc Working Group:

Peter Brandien	ISO New England Inc.
Glenn W. Brown	New Brunswick Power
Stephen L. Corey	New York ISO
Thomas J. Dutkiewicz	ISO New England Inc.
Larry Eng	Niagara Mohawk Power Corporation

Michael Falvo	Independent Electricity Market Operator
James W. Ingleson	New York ISO
Richard Mailhot	HydroQuébec TransÉnergie
Barry Milton	New Brunswick Power
Sasa Mizdrak	Independent Electricity Market Operator
John G. Mosier, Jr.	Northeast Power Coordinating Council
John Norden	ISO New England Inc.
Len Panzica	New York Power Authority
Charles P. Rusowicz	Consolidated Edison Company of New York, Inc.
Robert Sauriol	HydroQuébec TransÉnergie
Kateri Sparks	New York Power Authority
Howard A. Tarler	New York Department of Public Service
Karl Tammar	New York ISO
Robert W. Waldele	New York ISO

In parallel with the formation of the NPCC Sequence of Events Working Group, the BIT directed the NPCC Inter-Control Area Restoration Coordination Working Group to assess the restoration efforts of NPCC following the events of August 14<sup>th</sup>. The members of this Working Group include:

Members, NPCC Inter-Control Area Restoration Coordination Working Group (CO-11):

Alden Briggs	New Brunswick Power
<b>Chair, Inter-Control Area Restoration Coordination Working Group (CO-11)</b>	
Gregory A. Campoli	New York ISO
C. Steven Cooper	Independent Electricity Market Operator
Thomas J. Dutkiewicz	ISO New England Inc.
Stéphane Hénault	Hydro-Québec TransÉnergie
John G. Mosier, Jr.	Northeast Power Coordinating Council

Additionally, the Task Forces on Coordination of Planning and System Studies were immediately charged to assist in the simulation of the power system collapse, and all NPCC Task Forces were asked to pursue the lessons learned from the blackout. The following Working Groups assisted in these assignments:

Members, NPCC Working Group on Inter-Area Dynamic Analysis (SS-38):

Philip J. Tatro	National Grid USA
<b>Chair, NPCC Working Group on Inter-Area Dynamic Analysis</b>	
Eric H. Allen	New York ISO
Navin B. Bhatt	American Electric Power
Stephen D. Boutilier	Nova Scotia Power, Inc.
Kirit Doshi	Virginia Dominion Power
B. George Dunn	New York Power Authority
Daniel Fok	Independent Electricity Market Operator
William L. Harm	PJM Interconnection

Donald Izior  
Xiaochuan Luo  
Mohamed Mobarak  
Mahendra Patel  
Roy Pfleiderer  
Si Truc Phan  
Paul A. Roman  
Lai-Wan Szeto  
Guy V. Zito

Consumers Energy  
ISO New England Inc.  
New Brunswick Power  
Allegheny Power  
Niagara Mohawk Power Corporation  
Hydro-Québec TransÉnergie  
Northeast Power Coordinating Council  
Hydro One Networks, Inc.  
Northeast Power Coordinating Council

Members, Major System Disturbance Task Force (MSDTF):

Eric H. Allen  
Stephen D. Boutilier  
Robert W. Cummings  
Curt Dahl  
Kirit Doshi  
B. George Dunn  
Danny Fok  
Bill Harm  
Don Idzior  
Donal J. Kidney  
John Lawhorn  
Xiaochuan Luo  
Mohamed Mobarak  
Rob O'Keefe  
Mahendra Patel  
Si Truc Phan  
Paul A. Roman  
Charles P. Rusowicz  
Philip J. Tatros  
Phil Yum  
Jeff Webb  
Mohsen Zamzam

New York ISO  
Nova Scotia Power, Inc.  
North American Electric Reliability Council  
Keyspan Energy \* (representing LIPA)  
Virginia Dominion Power\*  
New York Power Authority  
Independent Electricity Market Operator  
PJM Interconnection  
Consumers Energy  
Northeast Power Coordinating Council  
Midwest ISO \*  
ISO New England, Inc.  
New Brunswick Power  
American Electric Power  
PJM Interconnection  
TransÉnergie  
Northeast Power Coordinating Council  
Consolidated Edison Company of New York, Inc.  
National Grid USA  
Tennessee Valley Authority  
Midwest ISO \*  
Consolidated Edison Company of New York, Inc.

\* Participated in base case development

Members, MAAC-ECAR-NPCC (MEN) Working Group:

John Andree  
Robert W. Cummings  
Curt Dahl  
Kirit Doshi  
Ugo Felli  
William L. Harm  
Larry Hodge

International Transmission Company  
North American Electric Reliability Council  
Keyspan Energy (representing LIPA)  
Virginia Dominion Power  
Independent Electricity Market Operator  
PJM Interconnection  
PJM Interconnection



Liana Hopkins  
Donal J. Kidney  
Ken Layman  
Xiaochuan Luo  
Scott Lockwood  
Olushola Lutalo  
Mohamed Mobarak  
Dale Osborn  
Mahendra Patel  
Si Truc Phan  
Paul Roman  
Charles P. Rusowicz  
Kim Sauerwine  
Joseph Smith

New York Power Authority  
Northeast Power Coordinating Council  
New York ISO  
ISO New England, Inc.  
American Electric Power  
Grid America  
New Brunswick Power  
Midwest ISO  
PJM Interconnection  
TransÉnergie  
Northeast Power Coordinating Council  
Consolidated Edison Company of New York, Inc.  
PJM Interconnection  
Midwest ISO

## 2.0 Executive Summary

All Areas of NPCC were operating within the Criteria, Guides and Procedures of the Northeast Power Coordinating Council as well as the Operating Policies of the North American Electric Reliability Council when the series of cascading contingencies in northern Ohio began on the 14<sup>th</sup> of August, 2003, ultimately leading to the widespread loss of load in Ontario, New York and New England. The Areas did not contribute to the various causes of the blackout itself, and thus the immediate focus of NPCC was on the restoration effort and a study of various preventive measures which could be employed to prevent or mitigate the impact of the kinds of events to which NPCC was subjected on August 14, 2003. Further, the assessment of cause is presented in the “U.S.-Canada Power System Outage Task Force Final Report on the August 14, 2003 Blackout in the United States and Canada: Causes and Recommendations.” For this reason, the challenge to NPCC was to focus on the following:

- Determine the critical sequence of events which occurred within NPCC on August 14<sup>th</sup>, summarized in Section 3.0;
- Provide the necessary resources to assist in the simulation of the events and the determination of the causes of the widespread blackout;
- Identify lessons learned from the restoration experience; and
- Identify measures which can be implemented in the future to prevent or mitigate a similar event in the future.

The restoration effort on the part of the NPCC Areas following the power system collapse of August 14, 2003, was generally timely and effective; no further collapse of the system was generated as the interconnected bulk power system was re-synchronized, and virtually all demand was restored within thirty hours. Despite the problems encountered during the restoration process, the NPCC system operators restored their respective systems in a timely, orderly and professional manner. The system operators of NPCC are to be commended for their actions during a difficult and demanding restoration. Further, the training programs within the Areas demonstrated their effectiveness in dealing with the wide range of challenges faced in restoring the NPCC systems. It must also be recognized that the overall restoration effort in NPCC was successfully realized in large measure by having in place mandatory reliability criteria requiring restoration plans within each NPCC Area as well as the testing of the key facilities and associated critical components necessary to establish a basic minimum power system for the purposes of restoration following a major system interruption. NPCC also significantly benefited on August 14<sup>th</sup> due to the clear lines of authority present in each NPCC Area directing the control of the bulk power system as well as the restoration process itself. A synopsis of the NPCC report on restoration, “Restoration of the NPCC Areas Following the Power System Collapse of August 14, 2003,” is provided in Section 5.0, and the recommendations of the report are presented in Section 6.0.

NPCC also actively assisted, and continues to do so, in the enormous task of simulating and analyzing the events of August 14, 2003. Section 4.0 details the efforts of NPCC in these tasks.

With the efforts concluded and put into place, the NPCC 2003 Blackout Investigative Team relinquishes all follow-up activities to the NPCC Reliability Coordinating Committee (RCC). The RCC will continually monitor the implementation within NPCC of all recommendations stemming from the studies cited in this report, and it has already put into place a rigorous tracking system to ensure that the recommendations of the *U.S.-Canada Power System Outage Task Force Final Report on the August 14, 2003 Blackout in the United States and Canada: Causes and Recommendations* as well as those recommendations developed by the North American Electric Reliability Council in the aftermath of the blackout of August 14, 2003, are carried out in a timely manner within NPCC.

### **3.0 Sequence of Critical Events in NPCC During the Power System Collapse of August 14, 2003**

On August 14, 2003, a cascading series of transmission and plant contingencies outside the boundaries of NPCC led to major power outages in Ontario, New York and parts of New England as well as the separation of the majority of New England and all of the Maritimes from the remainder of the system. In addition, although Hydro-Québec TransÉnergie (TE) lost a portion of its exports to the IMO, the NYISO and the ISO-NE at the time of the disturbance, the TE transmission system sustained the loss of these exports without significant impact.

The Reliability Coordinators of NPCC had no advance warning of the problems evolving in the Eastern Interconnection beyond the borders of NPCC. The sequence of events experienced by the NPCC Region culminated in the break-up of the bulk power grid and loss of 48,000 MW of load in NPCC within the span of a few seconds.

At approximately 16:09 EDT, the NPCC region experienced a significant change in power flows and frequency, which would prove to be the first indication of the events to follow. Prior to the appearance of this first swing, power flows in the NPCC Region, including its portion of the Lake Erie transmission loop, were typical for the summer period, and within acceptable limits. Transmission and generation facilities were in a secure state in all of NPCC. The critical events that occurred within the NPCC Areas were as follows:

At about 16:09, an increase in power flow from Pennsylvania, through New York and Ontario, and into Michigan was experienced.

Shortly afterward, between 16:10:38 and 16:10:41, a sudden large surge of power from Pennsylvania, through New York and Ontario, and into Michigan, concurrent with a sudden extraordinary increase in system frequency to 60.3 Hz, resulted in the beginning of circuit trips along the border between the Pennsylvania-New Jersey-Maryland Interconnection (PJM) and the NYISO. At the same time, power surged into New England and the Maritimes region of Canada. The combination of this power surge and the frequency rise resulted in the rejection of 380 MW of pre-selected Maritimes generation due to the operation of the New Brunswick Power “Loss of Line 3001” special protection system monitoring the status of system frequency and export flows on the 345 kV interconnection between the Maritimes and New England.

Between 16:10:39 and 16:10:44, the western PJM-NYISO 345 kV and 230 kV interconnections rapidly tripped in a west to east direction, followed immediately by the trip of the Branchburg - Ramapo 500 kV tie into the southeastern New York region. One out of three in-service tie lines between Ontario and Michigan was lost when Keith - Waterman 230 kV line tripped. Northwestern Ontario also separated from the rest of Ontario at this time,

leaving Northwest Ontario loads fed from the Eastern Interconnection via the Manitoba and Minnesota systems. Northeast New Jersey separated from the remainder of New Jersey, but remained tied to New York through the South Mahwah – Waldwick 345 kV and Hudson – Farragut 345 kV circuits. NPCC was then separated from the Eastern Interconnection but continued to supply power, via Ontario, into the eastern Michigan and northern Ohio load pocket, which had already separated from the Eastern Interconnection.

Over the period 16:10:46 to 16:10:49, a large power surge from New England to New York on their tie lines resulted in the effective separation of these Areas. At the same time, Vermont lost approximately 140 MW of load, and southwest Connecticut became isolated onto the New York system. The remainder of the New England Area and the entire Maritimes Area continued to operate as an electrical island. Within the same time interval, the State of New York effectively separated into eastern and western islands along the Central East/Total East transmission interfaces, with northeast New Jersey and southwest Connecticut tied to the eastern island.

Over the time period from 16:10:49 to 16:10:50, frequency declined below 59.3 Hz in parts of NPCC, initiating, as designed, automatic underfrequency load shedding in Ontario, eastern New York and southwestern Connecticut. In addition, large power swings between New York and Ontario resulted in the loss of nine internal 230 kV lines in Ontario, separating most of Ontario from New York and leaving the Ontario Beck and Saunders hydro stations radially connected to the western New York electrical island.

Between 16:10:50 and 16:10:56, the isolation of the Ontario hydro units onto the western New York island, coupled with underfrequency load shedding in the western New York island, caused the frequency in this island to rise to 63.0 Hz. At the same time, the now extremely generation deficient Ontario island frequency continued to decline towards 58.8 Hz, the threshold for the second stage of Underfrequency Load Shedding.

Between 16:10:56 and 16:11:11, three 230 kV lines re-closed automatically in Ontario, re-connecting western New York to Ontario; a few seconds later, Stage II of the underfrequency load shedding program activated in both Areas. After fourteen seconds the three lines that had automatically re-closed tripped a second time. With Ontario still supplying 2,500 MW to the Michigan-Ohio load pocket (until 16:11:57, when two remaining tie lines between Ontario and Michigan tripped), the Ontario system frequency declined towards a widespread shutdown at 16:11:58, resulting in the widespread loss of power to Ontario, including the cities of Toronto and Ottawa.

At 16:11:22, New England's Long Mountain to Plumtree 345 kV line tripped, leaving Southwest Connecticut connected to Northport, New York (Long Island), through the Norwalk Harbor to Northport 138 kV (circuit #1385)

submarine cable across Long Island Sound. In the next second, at 16:11:23, the two 345 kV circuits between the ConEdison and Long Island Power Authority systems tripped. The LIPA southwestern Connecticut areas remained connected through the Northport - Norwalk Harbor 138 kV circuit, but separated from the rest of the eastern NY island. At 16:11:45, the Northport - Norwalk Harbor circuit tripped, leaving the generation deficient southwest Connecticut and Long Island areas destined to collapse.

Within the western New York island, the boundary of which was slightly modified as a result of the re-closure of Fraser to Coopers Corners 345 kV at 16:11:23, the 345 kV system remained intact between the Niagara and Utica areas, and the St. Lawrence area remained connected to the Utica area through both the 765 kV and 230 kV circuits. Ontario's Beck and Saunders generation remained connected to New York at Niagara and St. Lawrence, respectively, and this island stabilized and remained intact throughout the disturbance.

As a result of the severe frequency and voltage changes, many large units in both New York and Ontario tripped. The eastern island of New York lost the heavily populated areas of southern New York, including New York City, Long Island and the northern New York City suburbs. At 16:11:29, the Edic – New Scotland 345 kV circuit reclosed, and the New Scotland to Leeds 345 kV path tripped, splitting the northern and southern sections of the eastern New York island, and reconnecting the remaining Albany area load to the western New York island.

At this point Ontario, New York and New England began the task of stabilizing the remaining electrical islands, restoring the transmission system and ultimately restoring customer load.

#### **4.0 NPCC Study and Simulation Efforts of the Power System Collapse of August 14, 2003**

The system studies portion of the Blackout Investigation consisted of the replication of the events that occurred on August 14, 2003 and “what if” analyses. This investigation work included: 1) steady state analysis using powerflow simulation and 2) dynamic simulation and analysis.

The powerflow simulation work was conducted by the MAAC-ECAR-NPCC (MEN) Working Group under the auspices of NERC. A large portion of the simulation and system analysis work was done by the NPCC representatives. The simulations for this first portion of the Blackout Investigation were conducted for conditions from 15:00 to 16:05 EDT. Following the outage of the Sammis-Star 345 kV circuit at 16:05 EDT it was no longer possible to obtain powerflow solutions and dynamic simulation was required to replicate system conditions after that time. Critical events modeled include:

- Conditions prior to the first major transmission outage including the outage of the Eastlake 5 Unit in the Cleveland area.
- Outage of the Harding-Chamberlin 345 kV circuit at 15:05:41 EDT.
- Outage of the Hanna-Juniper 345 kV circuit at 15:32:03 EDT.
- Outage of the Star-South Canton 345 kV circuit at 15:41:35 EDT.
- Outage of various underlying 138 kV circuits between 15:39 and 15:59 EDT.
- Outage of Sammis-Star 345 kV circuit at 16:05:57 EDT.

The overall powerflow study work included:

- Development and benchmarking of base cases for conditions prior to each major outage. The benchmarking involved comparisons to actual recorded system data.
- Simulation of the critical contingencies.
- Analysis of powerflow simulation results and “what if” testing. This work involved the development of comparison tables and graphical portrayal.

The steady state analysis work was conducted starting from immediately after the blackout in mid-August 2003 to December 2003. The results from this study work identified that, immediately after the first major outage, the system in the northeast Ohio area was above limits on a first contingency basis. They also identified that the loss of the Eastlake 5 Plant was critical to reactive power supply and voltage performance of the Cleveland area system. Results were included in the US-Canada Power System Outage Task Force Interim and Final Reports. In addition, presentations and direct input were provided from this work at the Blackout Technical Conferences in December 2003 in Philadelphia and January 2004 in Toronto.

The dynamic simulation work was conducted by the Major System Disturbance Task Force (MSDTF) also under the auspices of NERC. This group was essentially the

NPCC SS-38 Working Group including the necessary outside participants that normally would contribute to SS-38 studies. The dynamic simulation work started at the time when the steady state modeling work could no longer continue, which was 16:05:57 EDT. This was judged to be the point at which the cascade began, eventually leading to the large area blackout. The results of this study work were included in presentations and were provided as direct input at the Blackout Technical Conferences in December 2003 in Philadelphia and January 2004 in Toronto and at the New York and Ontario Technical Workshops in New York City during April, 2004 and in Toronto during July, 2004.

The overall dynamic simulation study work included:

- Development of the dynamic simulation case corresponding to the time of the Sammis-Star outage.
- Fine-tuning the dynamics model. This involved extensive work to ensure that all data used to model generators and control systems was valid and reasonable. This included excitation systems, governors, power system stabilizers, HVDC systems. Furthermore, this included the data used in standard program models and user written models. This work was essential to prevent bad data from causing numerical errors that would terminate simulations or give erroneous results.
- Simulation of all events from 16:05:57 EDT through 16:11 EDT, benchmarking of the simulation results versus recorded data and analysis of results. Simulation through this time period includes the massive power swing through New York and Ontario and its immediate reversal, generators losing synchronism and slipping poles in the Detroit area and the formation of islands beginning at 16:10:45 EDT.
- Analysis of the eastern New York island, the western New York island and the Ontario island by consideration of load-generation imbalance prior to the formation of the islands and in each island as the underfrequency load shedding stages operated and as generators were lost.

The dynamic simulation work started in October 2003 and is still continuing. The results of the work showed exceptional correspondence between the simulations and the recorded data through time 16:10:42. Around 16:10:42 the loss of synchronism of a group of Detroit area units required a great deal of effort by the MSDTF to model and properly benchmark. Simulations past that time to 16:11 EDT have been benchmarked and mark the beginning of the NPCC TFSS study work.

The NPCC TFSS Blackout Study includes the following tasks:

- Compilation of data for the studies. This has already been completed as part of the work done to this time.
- Replication of events through the period of study. As indicated above, this work has been completed to time 16:11 EDT, but the investigation of the conditions in the islands that had formed will continue past time 16:11.



- Evaluation of system and equipment performance during island formation, causes of islanding, and related possible mitigation measures.
- Evaluation of post-islanding performance and related possible mitigation measures.
- Evaluation of potential preventive mitigation measures.

## **5.0 Summary of the NPCC Restoration Efforts**

As each NPCC Control Area was in the process of assessing the current state of its area and that of its neighboring Control Areas, efforts immediately began to initiate the restoration process. The restoration effort following the power system collapse of August 14, 2003, was generally timely and effective. No further collapse of the system was generated as the interconnected bulk power system was re-synchronized, and virtually all demand was restored within thirty hours. The NPCC Region separated from the Eastern Interconnection primarily at the interfaces between PJM and the NYISO and between Michigan and the IMO. Internal to NPCC, the IMO was the most severely impacted Control Area, with a large portion of the province blacked out; only northwestern Ontario and several small load and generation pockets remained in service, with generation facilities at each end of Lake Ontario remained connected to Ontario and New York load. The NYISO experienced a widespread outage in the southeastern portion of New York state, south and east of the Total East interface. The NYISO separated from the Eastern Interconnection predominantly along the PJM-NYISO interface, with the exception of some northern New Jersey load that was left isolated on the NYISO system. Two large hydro facilities and the Hydro-Québec HVdc tie were the major facilities that remained in service, providing power to the remaining upstate load and the isolated northern New Jersey load. The ISO-NE separated from the NYISO primarily along its interface with New York, isolating the bulk of the ISO-NE and the Maritimes Control Area from the Eastern Interconnection. Portions of southeastern Connecticut remained connected to New York and collapsed with the southeastern New York area, and some New York load remained connected to the Vermont system of the ISO-NE. With the exception of the load lost in southeastern Connecticut and smaller pockets in Vermont, the ISO-NE remained largely intact. Within the Maritimes Control Area, New Brunswick Power observed the operation of its “Loss of Line 3001” special protection system due to the frequency excursions experienced.

From an NPCC perspective, the initial focus was to re-synchronize to the Eastern Interconnection, with the NYISO attempting to re-establish ties with PJM. The NYISO initiated communications with PJM and successfully re-synchronized with the Eastern Interconnection at 18:52 on August 14<sup>th</sup> through an automatic synchro-check relay on the Erie East (PJM) to South Ripley (NY) 230 kV tie line. The second tie, and the primary interconnection to PJM and the Eastern Interconnection, was established at 19:06 through the Ramapo 345 kV station, providing a stronger link between the PJM 500 kV transmission network and the NY 345 kV transmission network and accordingly a stronger system to support the continuing NY and IMO restoration process.

Following this effort, the ISO-NE and the NYISO worked to re-synchronize New England to New York. The two Control Areas agreed to make the initial attempt through the Alps (NY) to Berkshire (NE) to Northfield (NE) tie, with the synchronization at the Northfield generating station. In an effort to gain better voltage

control to support the effort, the NYISO energized a 345 kV loop from its southern tier, into the Albany area (Alps) and continuing through the northern portion of the Con Ed service territory. At 01:53 on August 15<sup>th</sup>, the ISO-NE and the NYISO successfully re-synchronized at the Northfield station. At this point, all of the NPCC Areas, the IMO, the NYISO, the ISO-NE, Québec and the Maritimes Area were now successfully re-connected with the Eastern Interconnection. As the restoration effort continued in the IMO, the NYISO and the ISO-NE, Area to Area tie flows were carefully monitored to ensure continuing load and generation as the restoration proceeded, and emergency assistance was provided among the NPCC Areas as required and as available.

For the Independent Electricity Market Operator (IMO-Ontario Area) and the New York Independent System Operator (NYISO-New York Area), which were severely impacted by the power system collapse, a critical element to their successful restoration was the rapid restoration of the basic minimum power system. A basic minimum power system is a transmission system that consists of one or more generating stations, transmission lines, and substations operating in the form of an island, permitting it to be re-started independently and subsequently re-synchronized to other islands or the main bulk power system. The transmission elements of the basic minimum power system connect units which have blackstart capability to those units without blackstart capability and include selected tie lines and corresponding sub-stations judged to be essential to the formation of the larger power system.

The two Areas of NPCC which were severely disrupted on August 14<sup>th</sup> established their respective basic minimum power systems as follows:

IMO	13 hours
NYISO	10 hours

Ultimately, the transmission systems in all three impacted NPCC Areas were effectively restored in their entirety as follows:

IMO	26 hours
New York ISO	30 hours
ISO-NE	9 1/2 hours

The restoration times above reflect the extent of the restoration efforts required within each Area.

The overall restoration effort in NPCC was successfully realized in large measure by having in place mandatory reliability criteria requiring restoration plans within each NPCC Area as well as the testing of the key facilities and associated critical components necessary to establish a basic minimum power system for the purposes of restoration following a major system interruption. NPCC also significantly benefited on August 14<sup>th</sup> due to the clear lines of authority present in each NPCC Area directing the control of the bulk power system as well as the restoration process itself. Rigorous

and enforceable criteria, and well defined authority, must be retained as the industry transitions to the NERC Reliability Functional Model.

Nevertheless, the complexity of reliably restoring supply to 48,000 MW of load in a timely manner identified the need for improvements in various areas, which are captured in the recommendations following in section 6.0.

## **6.0 NPCC Recommendations**

The following recommendations were derived by the NPCC Inter-Control Area Restoration Coordination Working Group in consideration of those determined from the individual Area reports and the contributions from system operators attending the NPCC System Operators Seminar held on May 5 and 6, 2004. It should be noted that there is no implied hierarchy in the order in which they are presented.

These recommendations are considered to be applicable to all NPCC Areas on a Region-wide basis, and they were approved by the NPCC Reliability Coordinating Committee on July 14, 2004.

### **Procedures and Training**

#### **Synchronizing of Electrical Islands**

Guidelines for matching voltage and frequency for the manual re-synchronization of electrical islands to be developed and incorporated in the “NPCC Inter-Control Area Power System Restoration Reference Document.” These guidelines would then be incorporated in each Area restoration plan to facilitate Area to Area re-synchronization, where applicable.

#### **Inadvertent Re-Synchronization**

Each Area to review the synchronizations made between electrical islands by automatic re-closing and determine if these re-closures were: a) appropriate; b) consistent with the normal, steady state design intent of the automatic re-closing systems; c) acceptable for the rare event which occurred on August 14, 2003. The inadvertent synchronizations done manually will be investigated, and methods to avoid manual inadvertent synchronizations in the future should be identified. Results are to be incorporated into switching procedures and training.

#### **Stabilization of Surviving Electrical Islands**

Each Area to review its restoration plan to address the actions necessary to stabilize operations in the remaining electrical islands following a major system separation.

#### **Load Shedding**

Each Area to ensure that its load shedding capability remains, where applicable, viable in restoration situations following a major system disruption.

#### **Operator Authority**

Each Area to continue to emphasize in its system operating procedures, job descriptions and operator training that its system operators possess the authority to take any action required, including load shedding, to comply with the NPCC Criteria and NERC requirements.

### **Restoration Training**

NPCC to develop plans for inter-Area restoration training drills, including those participants critical to restoration (such as Transmission Operators and Satellite Control Centers), simulating the restoration, the scope of which can include whole or partial Areas.

## **Communications**

### **Communications Management**

Each Area to review its voice telecommunication facilities and procedures to identify means to better; 1) manage call volume information, 2) prioritize communications and, 3) disseminate necessary information during major system emergencies.

## **Tools**

### **Alarm Management**

Each Area to review the ability of its Energy Management System (EMS) to buffer and prioritize alarms during a major system disturbance.

### **Wide Area View**

Each Area to provide its system operators with enhanced capabilities to permit a wide area view which will permit a more rapid assessment of the state of the interconnected bulk power system following a large scale system disturbance.

## **Criteria and Compliance**

### **Testing of Key Facilities and Associated Critical Components**

NPCC Document A-03, "Emergency Operation Criteria," defines a comprehensive program to identify, monitor and test the key facilities and associated critical components required to establish a basic minimum power system for purposes of restoration. This testing program to be further strengthened by incorporating these criteria requirements in NPCC Document A-08, "NPCC Reliability Compliance and Enforcement Program."

### **Restoration Criteria and Guides**

NPCC Document A-03, "Emergency Operation Criteria," and the "NPCC Inter-Control Area Power System Restoration Reference Document" to be reviewed to incorporate lessons learned from the restoration efforts.

### **Fuel Supply for Emergency Generators**

NPCC Document A-03, "Emergency Operation Criteria," to be modified to add a requirement to address adequate on-site fuel supplies for stand-by emergency generators associated with key facilities for restoration.

## Appendix A

### Glossary of Available Reports on the Power System Collapse of August 14, 2003

Report	Internet Address
“U.S.-Canada Power System Outage Task Force Final Report on the August 14, 2003 Blackout in the United States and Canada: Causes and Recommendations”	<a href="https://reports.energy.gov/BlackoutFinal-Web.pdf">https://reports.energy.gov/BlackoutFinal-Web.pdf</a>
Restoration of the NPCC Areas Following the Power System Collapse of August 14, 2003	<a href="https://www.npcc.org/publicFiles/blackout/currentYear/Restoration_of_the_NPCC_Areas.pdf">https://www.npcc.org/publicFiles/blackout/currentYear/Restoration_of_the_NPCC_Areas.pdf</a>
“IMO August 2003 Blackout- Restoration Evaluation Report”	<a href="http://www.theimo.com/imoweb/pubs/corp/EPTF_Aug2003_RestorationEvalRpt.pdf">http://www.theimo.com/imoweb/pubs/corp/EPTF_Aug2003_RestorationEvalRpt.pdf</a>
“Report of the NYISO Restoration Working Group on the August 14, 2003 System Event”	<a href="http://www.nyiso.com/topics/outage2003_info/investigation_data/nyiso_rwg_report_final.pdf">http://www.nyiso.com/topics/outage2003_info/investigation_data/nyiso_rwg_report_final.pdf</a>
“Blackout 2003-Performance of the New England and Maritimes Power Systems During the August 14, 2003 Blackout”	<a href="http://www.iso-ne.com/special_studies/August_Blackout_Report/">http://www.iso-ne.com/special_studies/August_Blackout_Report/</a>